

IS TILAPIA THE SAME PRODUCT WORLDWIDE OR ARE MARKETS SEGMENTED?

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ABSTRACT

Tilapia is one of the fastest growing aquaculture species in the world. It is produced and consumed in all continents and in more countries than most other species, making the market more heterogeneous than for other successful aquaculture species such as salmon and shrimp. This paper investigates the degree of market integration between tilapia from the three largest production regions, Asia, Africa and South and Central America. The study considers the different production methods, transport costs and qualities between the world's largest producers and determines whether tilapia products from different producers can essentially be considered the same product. This is important in order to understand the fast development of farmed tilapia worldwide and its prospects for future development.

Keywords: Tilapia, market integration

INTRODUCTION

The tilapia farming industry's rapid growth is interesting because in addition to impressive increases in the volumes produced, production is geographically spread throughout all continents and demand exists within a highly diverse market base.^a Tilapia is farmed in more than 80 countries worldwide, with production methods ranging from artisanal to intensive operations. Simultaneously, farmed tilapia is in high demand in many markets, ranging from highly developed to the poorest communities in developing countries.

One would assume that with such a variety of markets and widespread production, worldwide producers will supply tilapia to the most valuable markets. This, as for any good, will reduce differences in value between markets until the only difference left is the cost of transportation [1]. However, the large number of production environments and methods give rise to differences in quality and production costs. Different quality goods are often regarded as separate products and will, as such, command different market prices [2]. Also, differing production costs coupled with inadequate transport logistics and food safety issues can restrict the movement of tilapia to more profitable markets. This results in producers targeting specific markets and may create segmentation in the world's tilapia markets.

A significant factor that can separate developed and developing tilapia markets is their differing minimum quality standards. International developed markets require production methods to be compatible with the quality standards set by the Hazard Analysis and Critical Control Point (HACCP) system. This system is generally not required in developing markets. As a result, the production method chosen in developing countries will most likely influence which market is open to these producers and hence; the proportion of tilapia reaching different markets. This proportion is likely to affect the overall development of world tilapia markets as more than 95% of total farmed tilapia is produced in developing countries.

The largest producers of farmed tilapia are located in Asia, Africa and South and Central America.^b Significant quantities are supplied to local markets although overall exports have increased over time as a result of emerging markets in developed countries. Low production costs within these regions, coupled with high international prices, have made it very profitable to export tilapia. Nevertheless, the quantities of tilapia exported to international markets differ between countries because of different production and transport costs, exchange rates and product qualities. For example, China and Egypt are the world's first and second largest producers of farmed tilapia respectively.^c China has increased exports from 7% in 2002 to 22% of total farmed tilapia production in 2005,^d becoming the world largest exporter of tilapia [3]. On the other hand, Egypt does not export tilapia. High production costs and food safety concerns from the EU and US have kept most Egyptian tilapia in local markets, despite falling local prices [4].

International tilapia markets have expanded significantly from virtually nothing in 1991 to 340,000 tonnes live weight equivalents in 2005.^e This growth is mainly due to the expansion of the US tilapia market. The US imports three tilapia products: fresh and frozen fillets and whole frozen. This market has grown from no recorded imports in 1991 to 320,700 tonnes live weight equivalents in 2005. Producers exporting tilapia to the US have different competitive advantages, and specialise in different product forms. Factors affecting this are the producers' different levels of production cost and their geographical proximity to the US. As a result, Asia supplies most frozen imports into the US because of their low technological investment to produce tilapia [5]. South and Central America supply most fresh tilapia imports as a result of their relatively close proximity to the US.^f

The significant expansion of farmed tilapia production has, in terms of volume, situated this fish in the same league as farmed salmon. World farmed tilapia production has increased from 100 thousand tonnes in 1980 to over 2 million tonnes in 2005. Nevertheless, salmon is competitively exported all around the world despite being produced by a limited number of producers.^g Several studies have found a highly integrated market for salmon both globally, and for different product forms.^h Each product form or species may not be directly substitutable with one another but with so many species and product forms that are substitutable, it is possible to say that there is a common price determination process. This may not be the case for tilapia as fresh and frozen fillets imported into the US market have already been found to be separate products [6].

The purpose of this paper is to investigate the degree of market integration between tilapia from the three largest production regions. Imports into the US of fresh tilapia products from South and Central America and frozen tilapia products from Asia are used to represent the tilapia markets within these continents, as this will be the local markets opportunity cost. Fresh and frozen tilapia products from the largest Egyptian wholesale seafood market are used to represent tilapia prices at the African continent.

The results will be of interest to the tilapia industry in general as they may offer some insights into the future development of tilapia in world markets. By identifying the segmentation or integration of the tilapia market, we will also be able to speculate as to its future development. Will tilapia production follow that of salmon with only a handful of countries supplying other countries worldwide? Will tilapia still be produced by local producers for local markets with only a handful of countries supplying international markets? Will the global market of tilapia remain as it is today, with local markets being supplied by local producers and international markets being supplied by a wide range of producers? The results from this study will allow consideration of the development pathways that tilapia may follow.

In the analysis, we study the relationship between prices from January 2000 to December 2006. The development of prices overtime provides important information on the relationship between commodities. This has been recognised by economists such as [1, 7, 8]. Also, the literature has used prices to study the market integration between different seafood products.ⁱ

The present study will be organised as follows; in section 2, we discuss the situation of farmed tilapia as a worldwide produced species. In section 3, we discuss the data used in this analysis as well as the time series properties of the data. In section 4, we will describe the methodology. In section 5, we explain our empirical results and we present final comments in section 6.

BACKGROUND

Tilapia's basic biology, feeding and veterinary requirements has encouraged farmers to culture this fish in all continents using an array of different culture systems and management strategies.^j The variety of production methods makes it feasible to produce tilapia for subsistence, in large-scale commercial operations and at any point in between at a relatively low cost. Furthermore, the variety of production methods has resulted in world tilapia production growing rapidly in a relative short period of time. Figure 1 shows world farmed and wild tilapia production from 1980 to 2005. World wild tilapia production has only increased from 250,354 tonnes in 1980 to 669,935 tonnes in 2005. On the other hand, world farmed tilapia production has increased from 107,459 tonnes to 2,025,559 tonnes during the same period. This means world farmed tilapia production has increased from 30% in 1980 to 75% in 2005 of total world tilapia production.

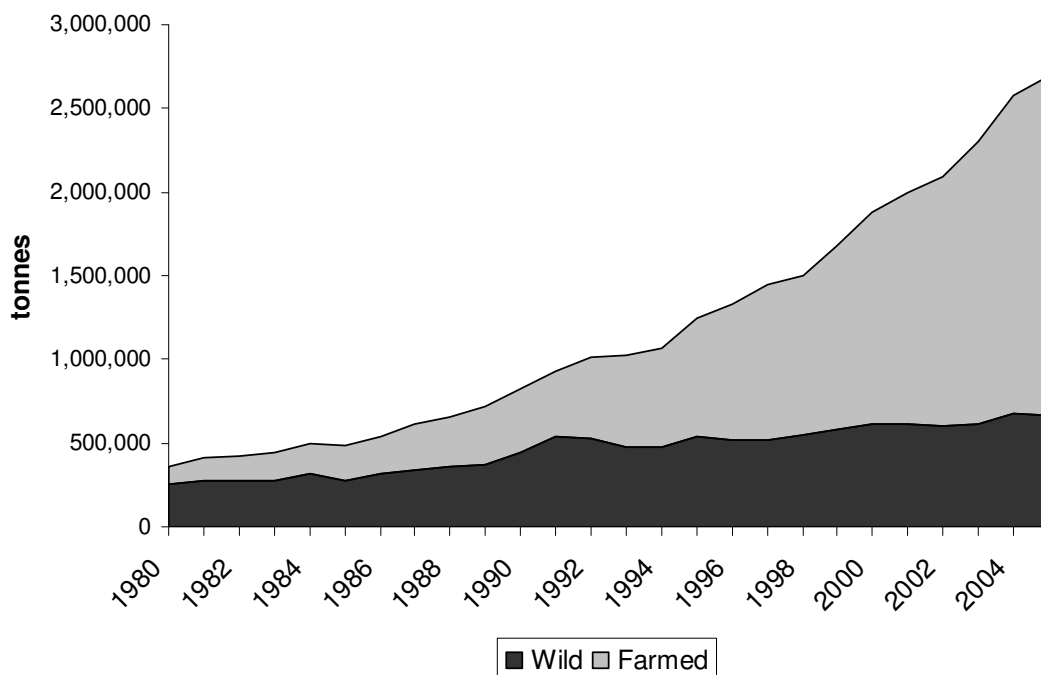


Figure 1. Annual quantities of farmed and wild tilapia produced worldwide, 1980-2005.

Source: FAO FishStat Plus. Global datasets, Aquaculture Production: Quantities and Capture Production

Farmers will decide what culture system and management strategy to use depending on their resources to build infrastructure, site characteristics, environmental conditions (in particular with respect to climate), socio-economic factors, technical knowledge, and marketing feasibilities. Nevertheless, the choice of production and management systems will affect the total costs of production.

In general, total tilapia production costs will be higher in temperate than in tropical countries because tilapia is a tropical fish that cannot live in cold waters [9].^k Therefore temperate tilapia producers need to invest in expensive systems if they want to grow tilapia. However, even within tropical areas, tilapia production costs will vary significantly between producers. In South and Central America costs range between \$1.20 and \$1.80/kg live weight [10]. In Egypt costs are approximately \$0.9/kg live weight, while in Asia they can be as low as \$0.50/kg live weight [11]. Overall, Asian tilapia producers face lower production costs than other continents because they require a lower technological investment [5].

Figure 2 presents the production of farmed tilapia in Africa, America and Asia from 1996 to 2005.^l Europe is not included because production is negligible at 320 tonnes in 1996, growing to only 578 tonnes in 2005. The largest producers are located in Asia followed by Africa and America. Tilapia production has increased in the three continents, although the growth in the American continent primarily represents that of South and Central America.^m Asian tilapia production represents approximately 80% of world farmed tilapia production. Asian tilapia production has increased from 713,384 tonnes in 1996 to 1,589,495 tonnes in 2005. Overall, and despite differences in production, the spatial distribution of tilapia indicates the adaptability of this fish to a wide range of environmental conditions.

The geographical concentration of tilapia farming is even more evident if production from the largest farmed tilapia producers is compared to world farmed tilapia production. Table 1 presents the growth in production of the seven largest producers of farmed tilapia worldwide from 1996-2005. China and Egypt are the largest producers of farmed tilapia followed by Indonesia, Philippines, Thailand, Taiwan and Brazil. From table 1, in 2005, the production of farmed tilapia by the seven largest producers represented respectively 48%, 11%, 9%, 8%, 5%, 4%, and 3% of world farmed tilapia production. Egypt has also had the largest growth with an almost seven-fold increase in farm production during these 10 years.

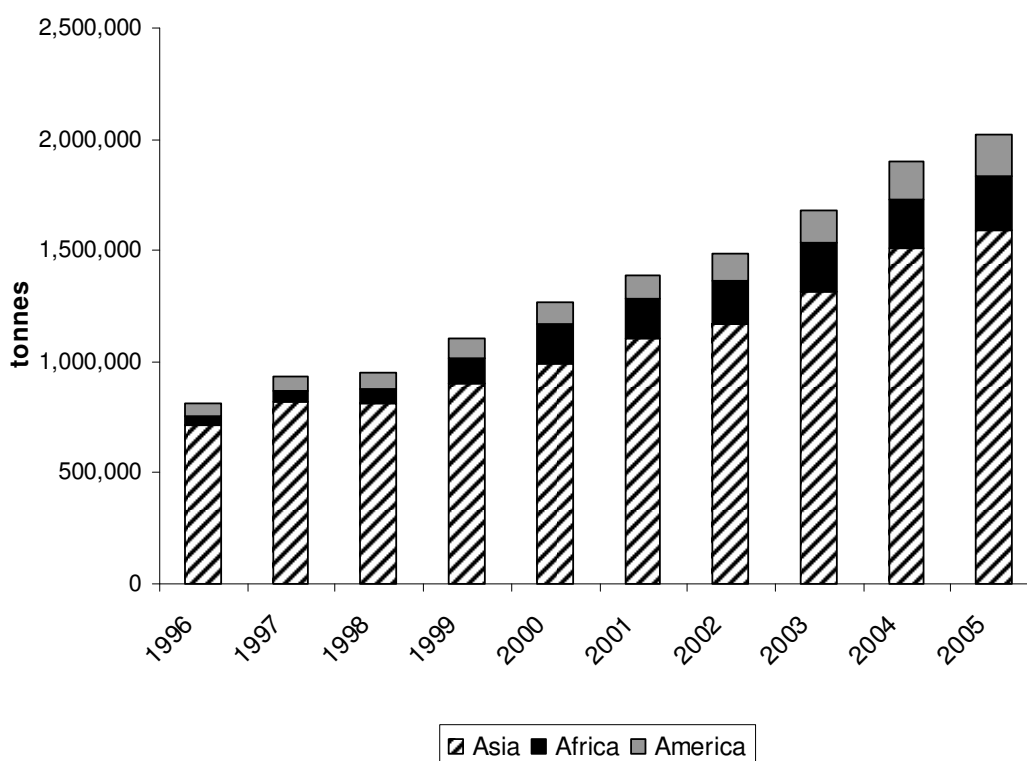


Figure 2. Annual quantities of farmed tilapia produced in Asia, Africa and America, 1996-2005.
Source: FAO FishStat Plus. Global datasets, Aquaculture Production: Quantities

Table 1
Total farm production of the seven largest producers from 1996-2005

Year	China	Egypt	Indonesia	Philippines	Thailand	Taiwan	Brazil	World Total
1996	394,745	27,854	75,473	79,415	91,038	44,756	15,700	810,103
1997	486,538	30,416	73,222	91,834	91,580	42,158	16,845	931,061
1998	526,984	52,755	65,894	72,023	73,809	36,126	24,062	950,619
1999	562,879	103,988	74,005	83,832	76,621	57,183	27,104	1,103,691
2000	629,795	157,425	85,179	92,579	82,581	49,235	32,459	1,269,883
2001	672,307	152,515	105,106	106,746	84,510	82,781	35,830	1,385,134
2002	706,996	167,735	109,768	122,399	83,936	85,059	57,031	1,504,197
2003	806,580	199,557	123,748	129,996	98,376	85,351	64,857	1,685,851
2004	897,756	199,038	139,651	145,869	160,407	89,275	69,078	1,899,400
2005	978,653	217,019	189,570	163,004	155,065	83,435	67,851	2,067,685

Source: FAO FishStat Plus. Global datasets, Aquaculture Production: Quantities

The large numbers of tilapia producers around the world makes it a complex task to analyse the global market of tilapia. One can use imports into the US of frozen and fresh tilapia products to represent the prices in the Asian and South and Central American market respectively. This is because over 96% of total US imports of whole frozen tilapia and frozen tilapia fillets have been imported from Asia between 2000 and 2006 and over 97% of total US imports of fresh tilapia fillets have been imported from South and Central America during the same time period.ⁿ Moreover, the US is the main import market for these exporters. Therefore, the export price to the US represents the opportunity cost for fish consumed locally. Also, Egypt can represent African markets as this country is the major producer of farmed tilapia in this continent (FAO FishStat Plus. Global dataset, Aquaculture Production: Quantities).

This may be a more questionable assumption, as there is virtually no trade between Egypt and other African markets. However, if this assumption is not correct, the results will understate the heterogeneity of the African tilapia market.

In Egypt, El-Obour wholesale market is the largest and most important fish market in the country [4]. This market supplies whole fresh tilapia and frozen tilapia fillets. The majority of Egyptian tilapia is sold whole fresh as this is the preferred product form. El-Obour market mainly supplies three different grades of whole fresh tilapia according to quality and size.^o In particular, tilapia grade 1 is the most popular as its quality is the highest and its size the largest (1-5 fish/kg). Frozen tilapia fillets are supplied as one single grade mostly to restaurants and hotels catering for high income Egyptians and tourists.

Figure 3 presents the annual volumes in tonnes of different tilapia products in the Egyptian and US market from 2000 to 2006. US tilapia imports are presented on the left vertical axis and Egyptian production on the right vertical axis due to the large differences in volumes between both of these markets.^p For the Egyptian market, wholesale quantity of whole fresh tilapia (grade 1) and frozen tilapia fillets from El-Obour market are presented. For the US market, imports of fresh tilapia fillets from South and Central America as well as imports of frozen tilapia fillets and whole frozen tilapia from Asia are presented. From Figure 3, all US imports have increased continuously over time. Egyptian whole fresh tilapia has also increased in the market except in 2003 and 2004 when supply dropped. The quantities of Egyptian frozen tilapia fillets follow to some extent an opposite trend to Egyptian whole fresh tilapia. Quantities of frozen fillets increased to a peak in 2003 but declined thereafter.

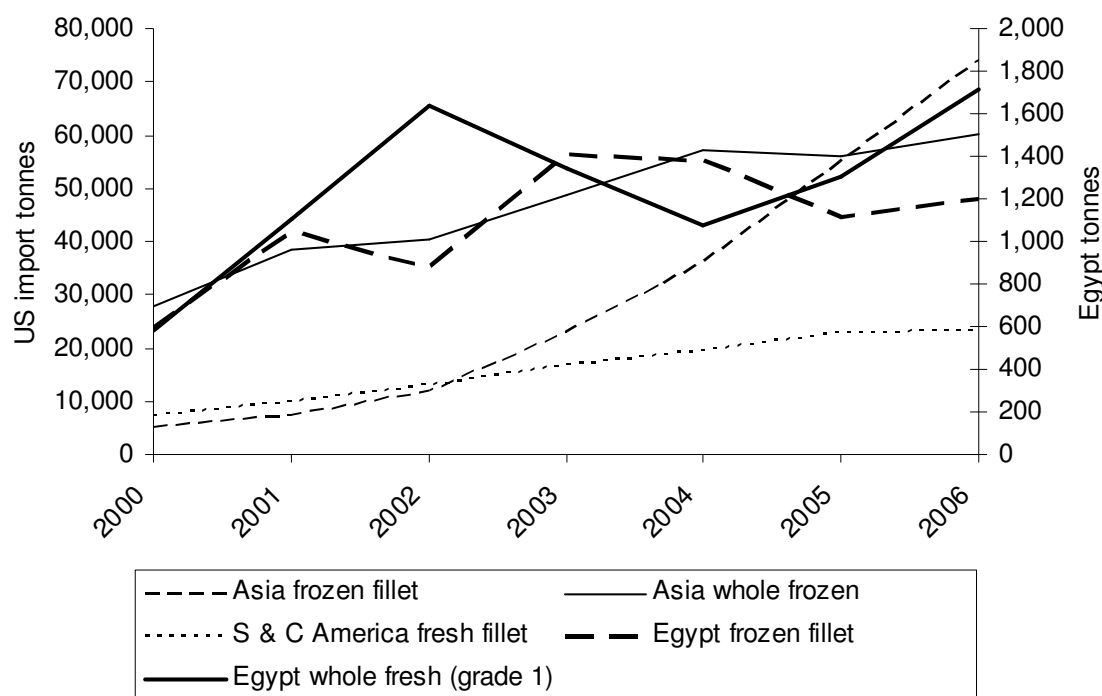


Figure 3. Annual US imports of whole frozen and frozen tilapia fillets from Asia and fresh tilapia fillets from South and Central America as well as El Obour wholesale quantities of Egyptian whole fresh tilapia (grade 1) and Egyptian frozen fillets from 2000 to 2006

Source: Obour market wholesale data and NMFS, foreign trade data

Figure 4 presents the evolution of prices from January 2000 to December 2006 for whole fresh tilapia (grade 1) and frozen tilapia fillets in the Egyptian market, as well as US import prices of whole frozen tilapia and frozen tilapia fillets from Asian countries and fresh tilapia fillets from South and Central American countries. For the US market, prices of frozen import products have declined over time, while fresh fillet import prices have increased at a consistent rate since the year 2000. Prices of Egyptian whole fresh tilapia and frozen fillets show similar patterns. These prices have declined continuously until December 2003 and increased thereafter.

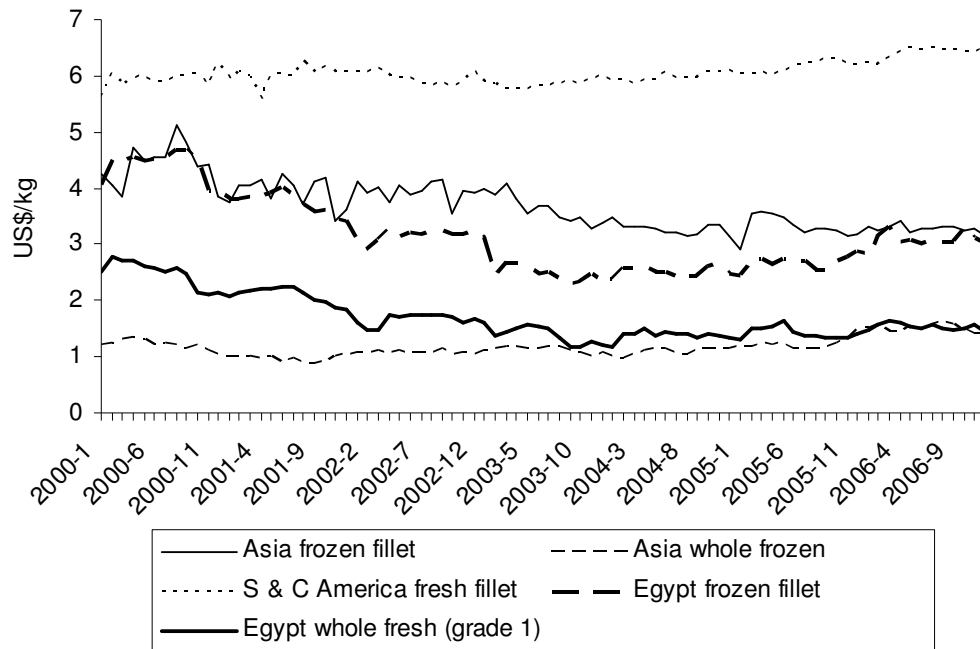


Figure 4. Monthly US import prices of whole frozen and frozen tilapia fillets from Asia and fresh tilapia fillets from South and Central America as well as El Obour wholesale prices for Egyptian fresh tilapia (grade 1) and Egyptian frozen fillets from 2000 to 2006

Source: Obour market wholesale data and NMFS, foreign trade data

DATA

The increase of tilapia imports into the US market have mainly occurred in this century; before this date import quantities of fillets were very limited, resulting in prices being very unstable. Consequently, our analysis concentrates on monthly price data from January 2000 to ensure a sensible analysis. The latest data available for El-Obour market at the time of analysis was December 2006. This results in a total of 84 observations. The variables investigated from the US market are import prices for Asian whole frozen tilapia, Asian frozen tilapia fillets and South and Central American fresh tilapia fillets. For the Egyptian market, two price variables are considered; whole fresh tilapia (grade 1) and frozen tilapia fillets. The data on US tilapia imports have been obtained from the National Marine Fisheries Survey (NMFS). The price data from the Egyptian market has been obtained from El-Obour market. The price figures have been converted from Egyptian pounds into US dollars in accordance with the official interbank exchange rate for the purpose of performing the analysis.

To investigate the market integration of different products of tilapia from different international producers, we have first studied the time series properties of the data using unit roots tests⁹. We have used the Augmented Dickey Fuller (ADF) unit root test [12,13]. The main idea of the unit root test is that if the price data in levels is found to be non-stationary ($I(1)$), this series does not have a constant mean, variance or covariance and a regression including this data will result in a spurious regression. However, if this price series combine with another non-stationary price variable then we obtain a stationary cointegration relationship and these two series together provide a significant economic relationship.

In the ADF test we need to set the adequate lag length to achieve white noise in the error term. We have done this by using the Schwarz information criteria and autocorrelation tests (LM). ADF tests for each series have been performed in levels and first differences with a constant as well as a constant and a trend. The null hypothesis in the ADF test is that each data series is $I(1)$. Table 2 identifies nominal prices to be non-stationary in levels and stationary in first differences $I(1)$.

Table 2

Unit root test (Augmented Dickey Fuller Test) Tilapia logged nominal prices, January 2000 – December 2006 (n = 86)

Variable	Levels		First Differences	
	Constant	Constant & Trend	Constant	Constant & Trend
US imports fresh fillet ¹	-0.380 (4)	-1.254 (4)	-6.286* (3)	-6.368* (3)
US imports frozen fillet ²	-1.124 (2)	-3.356 (2)	-10.457* (1)	-10.394* (1)
US imports whole frozen ²	-1.275 (0)	-2.158 (0)	-9.078* (0)	-9.150* (0)
Egyptian whole fresh	-1.854 (0)	-1.825 (0)	-8.348* (0)	-8.450* (0)
Egyptian frozen fillet	-1.552 (0)	-1.304 (0)	-9.564* (0)	-7.901* (1)

The values in brackets indicate the number of lags

* Indicate significance at 1% level; ** indicate significance at 5% level.

¹ US import prices from South and Central America

² US import prices from Asia

TESTING FOR MARKET INTEGRATION

Cournot [1] defined a market as follows: “It is evident that an article capable of transportation must flow from the market where its value is less to the market where its value is greater, until difference in value, from one market to the other, represents no more than the cost of transportation”. Other definitions of a market apply this concept not to a geographical space but to product space, so quality differences will take the place of transportation costs [2]. Therefore, prices of related products may deviate from each other in the short run, but in the long run, arbitrage and substitutability will guarantee that these prices form an equilibrium relationship (that is, they are cointegrated). A variety of seafood studies have examined the market relationship between different goods by analysing their prices with tests for cointegration.^f

Two approaches are generally used to test for cointegration: the Engle and Granger test [14] and the Johansen test [15]. Our study uses the Johansen test in the market integration analysis because it will also allow us to test hypothesis (e.g., law of one price (LOP)) on those variables that are found to have an equilibrium relationship. In our study, we test for market integration between two price series at a time. The Johansen test is based on a vector autoregressive (VAR) system. We start by setting a vector \mathbf{z}_t containing two (N) of the price series we are investigating. Then, we model \mathbf{z}_t as an unrestricted vector autoregression (VAR) model with “ k lags” containing these variables in levels, where, \mathbf{z}_t is ($n \times 1$) and each of the Π_i is an ($n \times n$) matrix of parameters. The system is in reduced form with each variable in \mathbf{z}_t regressed on only lagged values of both itself and all other variables in the system. Then, the VAR model is turned into a vector error correction model (VECM) of the form:

$$\Delta \mathbf{z}_t = \Gamma_1 \Delta \mathbf{z}_{t-1} + \dots + \Gamma_{k-1} \Delta \mathbf{z}_{t-k+1} + \Pi \mathbf{z}_{t-k} + \mu_t \quad (\text{Eq. 1})$$

where $\Gamma_i = -(I - \Pi_1 - \dots - \Pi_i)$, ($i = 1, \dots, k-1$), and $\Pi = -(I - \Pi_1 - \dots - \Pi_k)$. The Johansen test centres on an examination of the Π matrix. Π_k is the long-run “level solution” to (1), because in equilibrium, all the first differences of the price series ($\Delta \mathbf{z}_{t-i}$) will be zero, and setting the error terms, μ_t , to their expected value of zero will leave $\Pi \mathbf{z}_{t-k} = \mathbf{0}$. Furthermore, $\Pi = \alpha \beta'$, where α represents the speed of adjustment, while β is a matrix of long-run coefficients, such that the term $\beta' \mathbf{z}_{t-k}$ in equation (1) represents up to ($n-1$) cointegration relationships.

There are two asymptotically equivalent tests for cointegration in the Johansen framework: the maximum eigenvalue test and the trace test. The test for cointegration between the \mathbf{z}_t is calculated by looking at the rank of the Π matrix

via its eigen values. The rank of Π_k , r , determines how many linear combinations of z_t are stationary. If $r = N$, the variables in levels are stationary. If $r = 0$, none of the linear combinations is stationary ($\Pi_k = 0$). When $0 < r < N$, there exist r linear stationary combinations of z_t , or r cointegration vectors. In this instance, we need to determine how many $r \leq (n-1)$ cointegration vectors exist in β . Thus the last $(n-r)$ columns of β are non-stationary and do not enter equation (1). This amounts to equivalently testing which columns of α are zero. Therefore, it is possible to reduce the dimensions of α and β to $(n \times r)$ by factorising Π . If the series are cointegrated, we further investigate whether the two price series are imperfect substitutes or whether they are perfect substitutes (LOP) so their relative price is constant. We test for the LOP by imposing the restriction $\beta' = (1, -1)'$.

EMPIRICAL ANALYSIS

To investigate the degree of market integration in the tilapia market, we perform bivariate Johansen cointegration tests^s [15] between the five price series of interest. The results are reported in Table 3. As one can see, all of the pairwise tests, fail to reject the null hypothesis of no cointegration vector with rank = 0 at the 5% level.

Table 3
Bivariate Johansen test for cointegration, January 2000 – December 2006 (n = 84)

Nominal prices	Null Hypothesis ^a			
	Rank (ρ) = 0		Rank (ρ) ≤ 1	
	Max ^b	Trace ^c	Max ^b	Trace ^c
Egypt whole fresh / Egypt frozen fillet	8.02	8.18	0.16	0.16
Egypt whole fresh / US fresh fillets	6.53	7.11	0.58	0.58
Egypt whole fresh / US frozen fillets	7.83	8.91	1.08	1.08
Egypt whole fresh / US whole frozen	5.03	5.68	0.65	0.65
Egypt frozen fillets / US fresh fillets	4.93	5.72	0.79	0.79
Egypt frozen fillets / US frozen fillets	5.76	7.10	1.34	1.34
Egypt frozen fillets / US whole frozen	4.47	4.86	0.39	0.39
US fresh fillets / US frozen fillets	1.84	2.64	0.80	0.80
US fresh fillets / US whole frozen	3.81	4.92	1.11	1.11
US frozen fillets / US whole frozen	1.90	2.25	0.36	0.36

Results from Schwarz IC

a. The null hypothesis is that the number of cointegrating vectors is equal to ρ

b. Maximum eigenvalue test; c Trace test

* Indicates significance at the 1% levels; ** indicates significance at the 5% level

These results indicate there is no long-run relationship between imports of frozen tilapia products (whole and fillets) and fresh tilapia fillets in the US market. The lack of relationship between fresh and frozen fillets in the US market has already been reported by [6]. Furthermore, the results indicate no long-run relationship between imports of whole frozen tilapia and frozen tilapia fillets in the US market. Therefore, we can say from our results that none of the tilapia products imported into the US are in the same market. This indicates that there are three different market segments of tilapia in the US, where the segmentation is by product form. The lack of relationship between the imported Asian frozen tilapia products and South and Central American fresh tilapia products may not be too surprising; given the significant difference in transportation costs between these two continents. However, it is somewhat surprising that it does not seem to be arbitrage opportunities between whole and frozen fillets. This indicates that, despite these two frozen products being imported from Asia, processing costs have a significant impact on the production costs for fillets.

The market integration tests for the two Egyptian tilapia products, namely whole fresh (grade 1) and frozen fillets, indicate these two tilapia products do not form a long-run relationship in the Egyptian market. This may not come as

a surprise as Egyptians prefer fresh to frozen fish [4]. In addition, the market integration tests indicated that none of the Egyptian tilapia products compete with any of the three tilapia products imported into the US market. This result was also expected since the quality of Egyptian tilapia is too low for international standards [16]. Therefore, the tilapia products imported into the US market cannot be considered to be the same to the Egyptian products supplied to the market in Egypt. Finally, given that none of the prices have been found to be related, we have not tested for the Law of One Price (LOP).

DISCUSSION AND CONCLUSIONS

The purpose of this paper has been to investigate whether tilapia products from the three largest tilapia producing regions, Asia, Africa and South and Central America, as well as different product forms can essentially be considered the same product. This is important because the increase in international trade is likely to raise competition between tilapia producers across regions wanting to reach the most profitable markets. Given that the competitiveness of producers is very different,¹ it is likely that in an integrated market some producers will be forced out of international markets. This situation would change the global market of tilapia from as it stands today, where local markets are supplied by local producers and international markets are supplied by a wide range of producers. In the future, an integrated global tilapia market may resemble salmon markets with only a few producers supplying local and international markets. This could have negative social and economic implications for developing countries because; the livelihoods of small scale producers currently supplying local markets would be disrupted; and the benefits to the local economy of supplying international markets would cease in countries that are excluded. Alternatively, local tilapia markets could continue being supplied by local producers while international markets are only supplied by a handful of producers. This situation would still have negative economic implications for those countries that are forced out of international markets.

Our results indicate no long-run relationship between imports of frozen tilapia products (whole and fillets) and fresh tilapia fillets in the US market. The lack of competition between fresh and frozen tilapia products is likely to be the result of varying production technologies, quality and/or transportation costs between different tilapia producer countries [6]. In particular, both frozen tilapia products are supplied by South-East Asian countries, while fresh tilapia fillets are imported from South and Central American producers. Furthermore, freshness has been identified as the most important attribute determining retailer preference for tilapia [17]. Therefore, the lack of competition between fresh and frozen tilapia may also be due to consumers differentiating between these two products.

The results also indicate no long-run relationship between imports of whole frozen tilapia and frozen tilapia fillets in the US market. This probably occurs due to the change in consumers' lifestyle in the US. Consumers are increasingly demanding seafood products, such as fillets, that are nutritious, require less preparation time and are easier to produce [18,19]. Therefore, US consumers are likely to deem that these two frozen tilapia products are not substitutes for one another. Our results for the US tilapia market lead us to the conclusion that none of the tilapia products imported into the US are in the same market.

The market integration tests for the Egyptian tilapia market have been performed on the highest quality whole fresh tilapia (grade 1) and frozen tilapia fillets. Our results indicate no long-run relationship between these two tilapia products. The lack of relationship is likely due to Egyptians' preference for fresh to frozen fish [4]. A. Nasr-Alla (2006, pers. comm., December 05) has also suggested that different consumer groups buy different tilapia products. Whole fresh tilapia (grade 1) is likely to be mainly bought by restaurants and high income Egyptians. On the other hand, frozen tilapia fillets are most probably bought by hotels which mainly cater for foreigners in Egypt. As a result, the niche markets for differing tilapia products are likely to keep whole fresh tilapia and frozen tilapia fillets segmented within Egypt.

Finally, our results have indicated there is no long-run relationship between the tilapia products imported into the US market and the tilapia products investigated in the Egyptian market. The results come as no surprise as the quality of Egyptian tilapia products are below international standards [16]. These results indicate that the tilapia products from the largest producing regions in Asia, Africa and South and Central America cannot be considered to be the "same" product. Therefore, we can conclude that despite the differences in competitiveness across different regions, the large range of producers supplying different products to local and international markets will prevail at least for the near future.

In the long-run, we can speculate that; the development of vertically integrated large-scale operations coupled with low production costs at the high technological end; may lead to the evolution of an industrial concentration similar to that witnessed in farmed Atlantic salmon [11]. This situation would change the structure of world tilapia markets. Many producers in developing countries currently supplying international markets with traditional production methods would be out competed. As a result, the number of countries supplying tilapia to international markets would decline. Nevertheless, the difference in the quality demanded in developing and developed tilapia markets is likely to allow local producers to continue supplying local markets.

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ENDNOTES

^a World farmed tilapia production has increased from 485,000 tonnes in 1992 to 2,026,000 tonnes in 2005 (FAO FishStat Plus, Global datasets, Aquaculture Production: Quantities).

^b In 2005, these continents respectively contributed 78%, 12% and 9% of world farmed tilapia production (FAO FishStat Plus, Global datasets, Aquaculture Production: Quantities).

^c Farmed tilapia production in China (without Hong Kong) and Egypt were respectively 978,135 tonnes and 217,019 tonnes in 2005. These figures represent respectively 48% and 11% of world farmed tilapia production (FAO FishStat Plus, Global datasets, Aquaculture Production: Quantities).

^d Export statistics obtained from FAO FishStat Plus, Global dataset, Fisheries Commodities Production and Trade. In 2002, China exported 9,121 tonnes of frozen tilapia fillets, 73 tonnes of fresh tilapia and 20,833 tonnes of frozen tilapia fillets. In 2005, China's exports were 53,491 tonnes of frozen tilapia fillets, 21 tonnes of fresh tilapia and 38,761 tonnes of whole frozen tilapia. The live-weight equivalents were then calculated as 1.1 times the weight of whole tilapia and 3.3 times the weight of fillets [5,20].

^e FAO FishStat Plus, Global dataset, Fisheries Commodities Production and Trade statistics indicate in 2005; 73,261 tonnes of fresh and frozen fillets and 89,253 tonnes of whole fresh and frozen tilapia were exported. The live-weight equivalents were calculated as 1.1 and 3.3 times the weight of whole tilapia and fillets respectively [5, 20].

^f In 2006, South and Central America exported 100% of fresh fillets and Asia 99% of whole frozen and frozen fillets to the US (NMFS, Foreign Trade dataset)

^g Norway, Chile, Japan, US and Canada. See [21].

^h E.g., [22, 23, 24, 25]

ⁱ E.g., [22, 23, 25, 26, 27, 28, 29, 30, 31].

^j The culture systems are earthen pond, cage, concrete tank, and raceway. There are also many different management strategies (extensive, semi-intensive, intensive, monosex culture, mixed sex culture, monoculture, polyculture, and integrated with agriculture or animal husbandry).

^k In general, tilapia's lethal temperature occurs below 11°C. Reproduction is also best at water temperatures higher than 26.7 °C and it does not occur below 20 °C [32].

^l Africa includes the Middle East. Asia includes several islands in Oceania. America includes North, South and Central America.

^m South and Central America has produced more than 90% of the total farmed tilapia production in the American continent since 1999. The rest of production relates to North America which includes Bahamas and the United States of America (FAO FishStat Plus, Global datasets, Aquaculture Production: Quantities).

ⁿ Data obtained from the Foreign Trade dataset in the National Marine Fishery Survey Statistics (NMFS).

^o The region of Aswan also supplies whole fresh tilapia to El-Obour market although the large distance from Aswan to this market (over 1000 km) affects the freshness (quality) and hence its price compared to other whole fresh tilapia in El-Obour market.

^p The small quantity supplied by El-Obour market relative to the total farmed tilapia production in Egypt is partly because figure 3 only presents the wholesale quantities of whole fresh tilapia (grade 1) and frozen tilapia fillets from El-Obour market. Furthermore, farmed tilapia is also supplied directly to local markets as well as traders, retailers, hotels, restaurants, etc in the greater Cairo area [4].

^q All the unit root tests were performed with the econometric software package Eviews 5.

^r Applications to seafood data include [27, 29, 30, 31].

^s The Johansen cointegration framework was performed with the econometric software package EViews 5.0. The software allows the cointegration tests to be made using five different trend assumptions. We chose to have no intercept or trend in the cointegration test or VAR model following the Schwarz and Akaike information criteria.

^t The competitiveness of producers will vary due to differences in production and transport costs as well product qualities